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Swine Influenza A at Fort Dix, New Jersey (January–February 1976). III. Extent of Spread and Duration of the Outbreak

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RESULTS
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The extent and duration of transmission of influenza A/New Jersey/76 virus at Fort Dix, New Jersey, was examined with use of titers of hemagglutination-inhibiting antibody to influenza A/Mayo Clinic/74 (Hsw1N1) antigen as an index of infection. Five hundred ninety-three soldiers (a 9.3% sample) in basic combat training (BCT) were grouped in weekly cohorts by the date on which BCT was started. Cohorts with 11 of the 12 BCT cases of A/swine influenza began training on January 12, 19, and 26, 1976, respectively; 9%-19% of the trainees in these cohorts had titers of antibody to A/Mayo Clinic antigen of $\geq 1:20$. In five other cohorts without cases, which began training before January 12 or after January 26, 0-5% of trainees had titers of $\geq 1:20$. Titers observed in persons from military units not in BCT and in the civilian population of the post were not consistent with widespread transmission of the virus. Transmission of influenza A/New Jersey virus at Fort Dix probably occurred between mid-January and mid-February with little involvement of people outside of BCT units.

For the past 40 years, human infections with a swine influenza virus have been rare. In most cases, contact with swine was involved, and there was no significant human-to-human transmission [1, 2]. However, in early February 1976, a new strain of swine influenza virus, A/New Jersey/76 (Hsw1N1), produced clinical disease in five otherwise healthy soldiers at Fort Dix, N.J. A preliminary investigation could not link the cases with a common source or with animals. It did, however, uncover eight other patients with at least a fourfold rise in titer of antibody to influenza A/Mayo Clinic/103/74 (Hsw1N1) antigen [3]. An intense screening of febrile patients with acute respiratory disease in mid-

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February revealed only active transmission of A/Victoria/75 (H3N2) influenza virus; A/New Jersey virus was not detected. However, seroepidemiologic study of soldiers in basic combat training (BCT) [4] provided strong supportive evidence for earlier human-to-human transmission among the contacts of cases. This paper describes the steps taken to estimate the extent of A/New Jersey influenza transmission and to define the temporal limits of the outbreak at Fort Dix.

Materials and Methods

Recruits arriving at Fort Dix reported to a central reception center and were immediately formed into 50-member platoons. Over a three-day period, the trainees were immunized with influenza vaccine and processed into the Army. All platoons formed during the same week were organized into companies of four platoons each. After being formed, the platoons were kept relatively intact and semiisolated throughout BCT, especially for the first three weeks. During the period studied, an average of four to five companies were formed per week. A survey of antibody prevalence was performed in these discrete weekly training cohorts to estimate the time

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interval during which the disease spread among BCT trainees. For examination of the extent of the outbreak outside these companies and for consideration of other factors such as age, length of time at Fort Dix, and contact with BCT trainees, other personnel on the post were sampled with use of a variable sampling frame. Particular attention was given to sampling of training instructors, medical personnel, and dependents of soldiers. In addition, sera were obtained from a 10% sample of trainees entering the reception center during the period of February 21-27, 1976; five weeks later on April 1, 1976, blood samples were taken again from those individuals still available.

The seroepidemiologic study of BCT companies was undertaken by sampling 10% of all BCT trainees with use of the terminal digit of the Social Security number as the selection factor. The number "9" was chosen in random fashion and was used throughout the study to select the sample. Blood was taken from 10% of the trainees in advanced individual training (AIT), the next level of training after BCT, by the same system. In this group, particular attention was paid to those who had finished BCT prior to January 1976. Some of these AIT trainees had their BCT at Fort Dix in units formed as far back as August 1975, thus providing an index of trainee infections in prior cohorts of BCT. Instructors, the soldiers who trained BCT or AIT units, were sampled by the same method. In any other units that were studied on the post, the sampling frame was tailored to unit size (i.e., 10%, 50%, 100%) by varying the number of terminal digits selected. All medical personnel available on February 15-17, 1976 who had frequent contact with trainees were studied; only one of 51 persons declined to participate.

Blood was drawn by venipuncture in 15-ml vacuum tubes, and the serum was refrigerated at 4°C-6°C until frozen in dry ice or in a freezer at -20°C. These specimens were transported to the Walter Reed Army Institute of Research (Washington, D.C.) on wet ice, and titers of HAI antibody to influenza A/Mayo Clinic/103/74 (Hsw1N1), A/Victoria/3/75 (H3N2), and B/Hong Kong/5/72 antigens were measured as previously described [3].

A simple one-page questionnaire for selected

demographic variables was administered by trained corpsmen at the bleeding sessions.

An unbiased civilian sample was a much more difficult undertaking. For expediency, an experienced preventive medicine specialist was stationed at the phlebotomy section of Walson Army Hospital, Fort Dix, on March 1-4 and 7-10, 1976, to administer a simple questionnaire and to ask patients to allow an additional 15 ml of blood to be drawn for determination of titers of serum antibody to A/Mayo Clinic antigen. All volunteers were ambulatory care patients from the general outpatient and specialty clinics of the hospital. Specimens were collected and processed as described above. Information recorded on the questionnaire included age, sex, year of last influenza vaccination, reason for phlebotomy, history of recent illness or hospitalization for acute respiratory disease, and contact with swine. There were 428 volunteers in this group.

Results

Sample of BCT units. Six hundred thirty-five trainees assigned to BCT units were reported by their commanders to have a terminal digit "9" in their Social Security numbers. Blood samples were taken from 592 (93%) of these men representing 34 companies on February 15-27, 1976. Those not sampled were usually unable to attend the single bleeding session of their unit for various administrative reasons. At the time of the study, the three companies still on the post with cases identified by isolation of the A/New Jersey virus and the five companies with cases defined by serology constituted 8.8% and 14.7%, respectively, of the total of 34 companies surveyed. Based on these proportions, 52 men from the former companies and 87 men from the latter would be expected in a sample of 593. The actual numbers were remarkably close (51 and 83, respectively). The close agreement between expected and observed rates supports the assumption that the selected sample is representative.

The prevalence of HAI antibody to influenza A/Mayo Clinic antigen in platoons and units with cases has been shown to differ from that in units that did not have identified cases (contemporary units) [4]. Table 1 presents the preva-

Table 1. The prevalence of HAI antibody to influenza A/Mayo Clinic/103/1974 antigen and geometric mean titers of antibodies to selected influenza antigens in basic combat trainees grouped by first day of their initial training week, Fort Dix, N.J., 1976.

Week (1976)	No. of subjects sampled	No. (%) with A/Mayo Clinic/74 antibody titer of		Geometric mean of titers of $\geq 1:10$		
		$\geq 1:10$	$\geq 1:20$	A/MC/74*	A/Vic/75†	B/HK/72‡
1/5	26	1 (4)	0	1:10	1:56	1:49
1/12§	72	22 (31)	14 (19)	1:24	1:53	1:58
1/19§	86	18 (21)	10 (12)	1:17	1:76	1:57
1/26§	101	12 (12)	9 (9)	1:22	1:78	1:49
2/2	88	6 (7)	0	1:10	1:114	1:35
2/9	80	7 (9)	4 (5)	1:18	1:120	1:38
2/16§	69	4 (6)	1 (1)	1:12	1:109	1:50
2/23	70	3 (4)	2 (3)	1:16	1:98	1:29
3/1	22	1 (5)	0	1:10	1:50	1:14
RC#	39	0	0	0	1:19	1:67

*A/Mayo Clinic/103/74.

†A/Victoria/3/75.

‡B/Hong Kong/5/72.

§ Weeks with cases of A/swine influenza.

#Recruits from the reception center.

lence of A/Mayo Clinic antibody and the geometric mean titers (GMTs) of antibody to three influenza antigens for the 10% BCT sample; this sample includes all 34 active companies, one company that was forming to begin training on March 1, 1976, and a group of 39 recruits from the reception center who would begin training on March 1 or 7, 1976. These units represent distinct cohorts formed over 10 consecutive weeks. All units with cases were grouped over a three-week span in the middle of January except for unit B7, which started training on February 16, 1976. Although there was variation in prevalence of antibody among the small samples from individual units [4], when the units were grouped into weekly cohorts, the prevalence of measurable antibody to A/Mayo Clinic antigen in trainees who began BCT between January 12 and February 1 was higher than in units starting before or after these dates. Also notable was that the GMTs of antibody to A/Victoria antigen were higher for cohorts starting at a later date (February 2-23, 1976).

Retesting of the reception center and BCT samples. Five weeks after the original blood samples were drawn, 39 BCT members who were initially sampled in the reception center on February 21-27, 1976 were sampled again to determine whether any evidence for continued transmission of A/New Jersey virus could be detect-

ed. All A/Mayo Clinic antibody titers were $<1:10$ initially and remained so at five weeks. The GMT of antibody to A/Victoria virus, however, increased from 1:10 to 1:50, and the GMT of antibody to B/Hong Kong virus increased from 1:67 to 1:181; both titers rose, as expected, after immunization.

Units formed on February 16 and 23 were also retested; 56 and 53 members, respectively, from each group were sampled again and showed essentially no change in HAI antibody titers to A/Mayo Clinic antigen. Specifically, four specimens showed a one-tube dilution decline, none increased, and 144 were unchanged. This finding is of particular interest since one probable case came from a company formed during the week of February 16. The lack of a rise in titer of influenza A/swine antibody in units formed after February 16, along with the inability to isolate the agent in middle and late February, suggest an end to the transmission of swine influenza virus during the first week of February.

AIT trainees. One hundred eighteen AIT trainees were screened for antibody to influenza A/Mayo Clinic antigen. Of 15 females, only one had detectable antibody (titer, 1:10); all had undergone BCT elsewhere. Of the 103 males, eight (7.8%) had a titer of $\geq 1:10$, and six (5.8%) of these had titers of $\geq 1:20$. These proportions are consistent with a reported background preva-

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lence of influenza A/swine antibody of 0-8% at a titer of $\geq 1:20$ [3] and provide no evidence for A/New Jersey transmission in AIT units. This group includes at least 30 trainees who had arrived at Fort Dix prior to October 24, 1975.

Dependents and retirees. Table 2 shows the percentage of titers of HAI antibody to A/Mayo Clinic antigen of $\geq 1:10$ and $\geq 1:20$ in civilians (dependents and retirees) eligible for care at Walson Army Hospital. A peculiar age and sex distribution is immediately obvious. A high concentration of females in the young-adult age group reflects in part the younger age distribution of the military family and also the large input from the obstetrical clinic. The strikingly low prevalence of males 20-40 years old is due to the relatively small number of dependent husbands and sons in this age group. Despite these sample biases, there is an obvious tendency for an increasing antibody prevalence in successive age groups as has been shown by others [5, 6]. The observed titers could not be correlated with a history of illness, recent influenza immunization (within one year), history of hospitalization, or contact with swine.

Active-duty personnel other than trainees. Three major groups of military personnel other than trainees were studied to define the extent of spread of influenza A/New Jersey virus on the post and its relation to BCT contact. The permanent party group are soldiers responsible for the normal function and maintenance of the post and have little or no contact with trainees. Instructors are soldiers whose primary responsibility is training of BCT or AIT trainees and who

are in frequent contact with them. The medical staff form a special population who have a potential for rather intense contact with ill trainees; they are therefore considered separately from the permanent party.

Table 3 displays the prevalence of antibody to A/Mayo Clinic antigen in the three groups with 25 years of age as a dividing line. This age was not chosen arbitrarily. As noted in the prevalence data from nonmilitary beneficiaries as well as in results of other studies [5, 6], there is an increase in prevalence of antibody with age. Since the military cohort under age 25 would not be expected to have had exposure to H0, H1, or Hsw antigens and since Hsw antigen was last used in military vaccines in 1968 [7], a low prevalence of Hsw antibody was expected. Thus this group can serve as a sensitive index of A/New Jersey influenza transmission among soldiers who were not in BCT.

The overall prevalence of antibody to A/Mayo Clinic antigen in this age group was 5% with use of a titer of $\geq 1:20$ as an index. This prevalence is consistent with the background prevalence in other populations studied. It is interesting that the four individuals with titers of $\geq 1:20$ were either from units with cases or medical personnel. However, the numbers are too small to make any inferences. The prevalence of titers of $\geq 1:20$ in members older than 25 years was 28%; again, there was no striking trend demonstrated among these members by unit.

Two other groups of soldiers were studied and are presented separately. The veterinary group is a subset of the medical personnel on the post, but their exposure to animals or animal by-products and their lack of clinical contact set them aside from the rest of the medical center personnel. Fourteen men were tested; all eight individuals younger than 25 years had negative titers ($< 1:10$) to A/Mayo Clinic antigen. Of the remaining six members, three men aged 31, 35, and 44 years had titers of 1:10, and a fourth man, aged 30, had a titer of 1:20. A second population of interest, which was also analyzed separately from the three major groups, consisted of soldiers assigned to the reception center. Although they worked with BCT trainees, this contact, in general, was not intense or sustained. Trainees spend only three days in the reception center so

Table 2. Percentage of civilians with titers of HAI antibody to influenza A/Mayo Clinic/103/74 antigen of $\geq 1:10$ and $\geq 1:20$ by age and sex at the Phlebotomy Clinic, Walson Army Hospital, Fort Dix, N.J., February 1976.

Age (years)	Females			Males		
	No.	Percentage with antibody titers of		No.	Percentage with antibody titers of	
		$\geq 1:10$	$\geq 1:20$		$\geq 1:10$	$\geq 1:20$
<20	63	6	5	26	0	0
21-30	114	6	3	1	0	0
31-40	41	20	2	4	50	25
41-50	48	42	19	34	74	44
>51	37	97	92	60	98	88

Table 3. Titers of HAI antibody to influenza A/Mayo Clinic/103/74 (Hsw1N1) antigen in selected groups of soldiers who were not in training, Fort Dix, N.J., 1976.

Group	No.	<25 years old		>26 years old		
		No. with titer of ≥1:10	≥1:20	No.	No. with titer of ≥1:10	≥1:20
Permanent party*	29	1	0	12	5	2
BCT instructors in†						
Units with cases	9	4	2	11	7	3
Units without cases	9	0	0	23	17	7
Medical personnel						
Female	15	2	2	5	2	2
Male	15	2	0	9	6	3
All groups	77	9	4	60	37	17

* Soldiers responsible for post maintenance and not in contact with trainees.

† BCT = basic combat training.

any contact of trainees with this cadre is quite brief. In addition, many of the reception center staff are in administrative billets and have little interaction with the trainees. Twelve (20%) of 60 members ≤ 25 years of age had titers of antibody to A/Mayo Clinic antigen of 1:10, whereas 13 (26%) of 49 individuals older than 25 had titers of 1:10. None had titers of $\geq 1:20$, a finding which is unusual in comparison with data from other units. However, this unit was sampled five weeks after the other units, and the sera were tested separately.

Discussion

As has been noted [3], the initial effort was aimed at detection of influenza A/New Jersey activity at Fort Dix. There was a comprehensive screening program of all people with a febrile respiratory tract illness presenting at Walson Army Hospital; on four of the six days of this screening, the hospital was the only military treatment facility open. Influenza A/New Jersey virus was not identified in any specimens from 95 subjects tested. Since 58% of the subjects sampled had isolates of influenza A/Victoria virus, there is little doubt that the place, technique, and syndrome chosen for case-finding effectively screened for influenza. In view of the original discovery of cases by sampling of the same acute respiratory disease ward and the similarity of the clinical syndrome in A/Victoria patients, it is unlikely that clinical cases escaped detection. It is reasonable to assume then that the failure to isolate influ-

enza A/New Jersey virus means that the virus was no longer being transmitted at Fort Dix to any measurable degree. Also, paired sera did not show a rise in titer of antibody to A/Mayo Clinic antigen either in these patients or in BCT trainees who started training after February 16 and were tested again at five weeks. The last confirmed case of A/New Jersey influenza was admitted on February 9, 1976, and no evidence for further transmission was found after that date.

The beginning of the outbreak is more difficult to determine since the sampling for virus by throat washing was limited to only two days in January and events prior to this time can only be inferred. Of the four hospitalized patients from whom the virus was isolated, the earliest onset of illness recorded was on January 26, 1976, and the presentation of the fatal case was even later, February 3, 1976. The earliest serologically defined cases both claimed their date of onset of illness as January 12, with an interval between onset and hospitalization of seven and 14 days, respectively. These intervals are unusually long for influenza, and the possibility of a preceding acute respiratory disease must be considered. No serologic evidence of transmission was found in the small sample (two companies) of BCT trainees who began BCT at Fort Dix before the Christmas holidays. The low prevalence of antibody in AIT trainees who would have completed BCT in late 1975 and the low rates of acute respiratory disease reported by the Fort Dix preventive medicine officer prior to January 18, 1976 are evidence against significant transmission in

1975. Unfortunately, trainees of other units formed before the holiday season, including a unit with a confirmed case (D5), had departed prior to the epidemiologic investigation. Without this group's contribution, a more precise estimation of the beginning of the outbreak and a search for a specific source were not possible. The virus was most likely introduced to the trainee population soon after the Christmas holiday at the earliest and as late as the second or even third week of January.

In table 1, the prevalence of A/Mayo Clinic antibody can be compared with GMTs of A/Victoria antibody in weekly BCT cohorts. Prevalence is used to indicate the intensity of unit exposure to influenza A/New Jersey virus. Because there are so many trainees without detectable A/Mayo Clinic antibody, the GMT does not adequately reflect the unit's experience. On the other hand, the GMT is the appropriate indicator for exposure to A/Victoria virus since almost all trainees have detectable antibody to this strain. By these indicators, there is a clear separation of the peaks of the A/Victoria and A/New Jersey exposures in these units. It should be noted that the 39 reception center trainees studied five weeks after immunization had a GMT of 1:50, which is similar to that of the BCT cohorts formed on January 5 and 12. Companies formed between the times when these two groups were formed, from February 2 through February 23, have a GMT of A/Victoria antibody that is twice this level, a fact that probably reflects natural infection. On the other hand, the intensity of A/New Jersey activity would appear to be concentrated in units formed for training between January 12 and 26. This finding strongly suggests an initial wave of A/New Jersey infection which merged with and was followed by a wave of A/Victoria infection in the BCT population. It also provides further evidence that serologic changes, as measured by A/Mayo Clinic antigen, reflect mainly A/New Jersey infections in this population rather than heterotypic rises in titer of antibody to A/Victoria infection, recent immunization, or past exposure to the antigen.

After the initial presentation of these data, estimates of the total cases quoted in the media were as high as 500. If such a numerical estimate is made, more confidence can be placed in a

conservative extrapolation from the data with consideration for background prevalence of antibody. Such an estimate would exclude all sampled companies but the three with virologically proven cases (E1, C2, and C4). Next, only the proportion with a titer of $\geq 1:20$ ($16/51 = 0.314$) would be counted as an index of infection, and a 5% background prevalence would be subtracted. The resulting proportion (0.264) is multiplied by the estimated total strength of the involved companies (540) for a final estimate of 142 infections. All components of this estimate are very conservative; the estimate ignores the possibility of transmission in units with cases confirmed only by serology, in nonrecruit units, and in units not sampled but on the post at the time of the outbreak (including one unit, D5, with a known case), and possible cases associated with the virologically confirmed case in an AIT cadre. A somewhat less conservative approach would include the units with cases identified by serologic methods; this approach would increase the estimate to 230 infections. This estimate is still relatively conservative and again excludes two units with known disease.

Similar estimates of transmission in military personnel other than trainees would only be pure speculation. Unfortunately, the importance of age was not completely recognized at the time of the initial investigation, or the sampling would have been heavily biased toward young troops. As a consequence, the numbers in table 3 for the younger soldiers limit meaningful comparisons. They do, however, support assumption of a 5% background prevalence of A/Mayo Clinic antibody (titer of $\geq 1:20$). Age, sex, and the uncertain prior vaccine experience of older military personnel present too many confounding variables for these small samples to allow any estimate of whether the virus spread beyond the BCT population except for the confirmed case in an AIT office worker. This is also true of the civilian beneficiaries of Army health care, a heterogeneous population that could not be adequately sampled or controlled. Also, this latter group was sampled in a medical, not a community, setting and is thus a selected population.

Therefore, it appears that the outbreak of A/New Jersey influenza at Fort Dix, N.J., was due to the introduction of the virus sometime in early

to middle January 1976. The virus seemed to infect predominantly BCT recruits and, for unknown reasons, was not transmitted after the second week of February.

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